NuMI-B-343
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Neutrino Event Rate Comparison for Continuous Versus Discrete Decay Pipe Shielding

Abstract

The proposed discrete shielding configuration of the NuMI decay pipe produces a ν_μ^{CC} event rate that is 95% as large as the previous continuous shielding configuration. The wrong flavor neutrino rates are modestly smaller in the discrete shielding case.

1 Geometries

Two decay pipe geometries have been modeled using the GNUMI Monte Carlo.

- The "continuous" shielding case has a 1 m O.D. (0.98 m I.D.) decay pipe, which extends from 48 m after the end of the target to 793 m after the end of the target. In the GNUMI model used, the decay pipe is surrounded by continuous concrete shielding, as shown in Figure 1.
- The geometry for the "discrete" shielding is as discribed in "Status Update: Discrete Shield for NuMI Decay Pipe", S. Childress and G. Koizumi, 9/12/97, with two exceptions. The decay pipe end is taken at 793 m instead of 800 m for fair comparison to the continuous case. And the outermost radius of the concrete shielding is taken as constant, since it's exact shape is still under discussion - it is irrelevant for the neutrino rates in any case. Figure 2 shows the GEANT model of the discrete geometry.

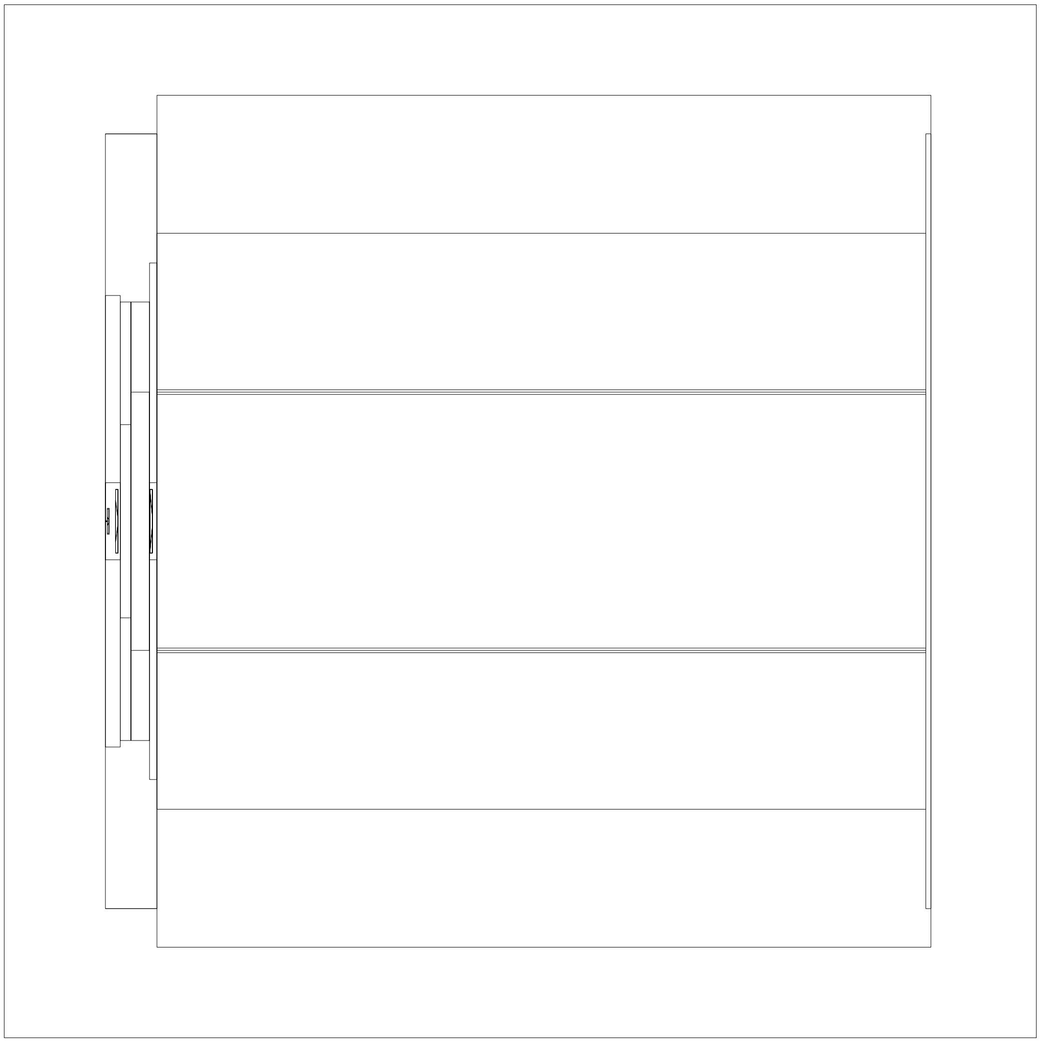

Figure 1: The continuous shield configuration.

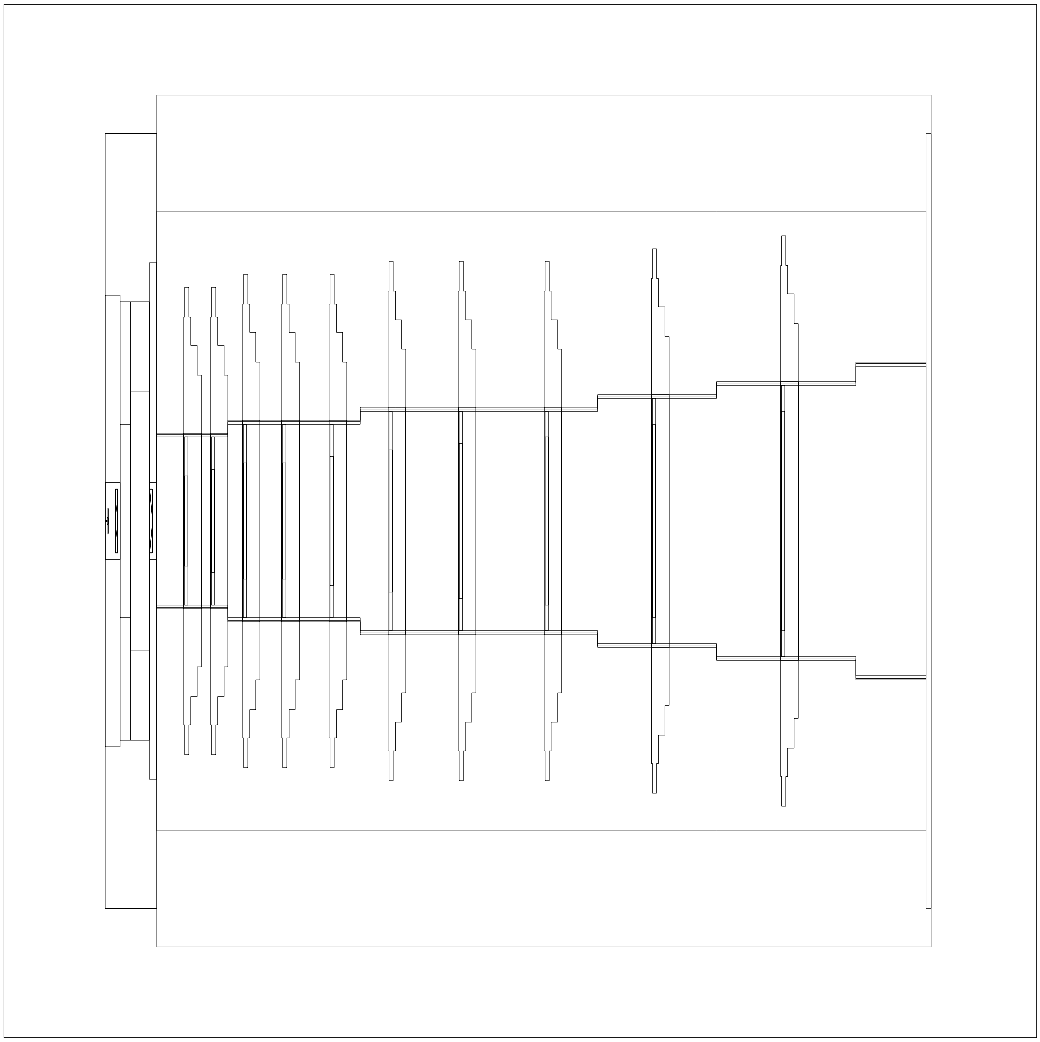

Figure 2: The discrete shield configuration.

2 Neutrino Spectra

The resulting ν_μ neutrino event spectra at the MINOS detector in SOUDAN are compared in Figure 3. The smaller effective radius of the discrete shielding results in a somewhat smaller event rate. Figure 4 displays the spectra for the background neutrino flavors as well. The total event rates are listed in Table 1. A "year" corresponds to the NuMI-standard of $3.7x10^{20}$ protons delivered on target. The results are from 2.4 million GNUMI events (protons on target) for each geometry, using the FLUKA/GEANT generator model in GEANT v3.21.08.

CC event rates per kilo-ton per year	Continuous Shielding	Discrete Shielding
ν_μ^{CC}	3857 ± 18	3674 ± 18
$\overline{\nu}_\mu^{CC}$	33.0 ± 1.5	28.5 ± 1.4
ν_e^{CC}	19.7 ± 1.3	17.6 ± 1.0
$\overline{\nu}_e^{CC}$	0.53 ± 0.05	0.48 ± 0.07

Table 1: Event rate comparison.

3 Secondary Interactions

Tables 2 and 3 break down the sources of neutrinos. The main division is by whether the parent of the neutrino was produced in the target or in one of the other regions listed (i.e. a secondary interaction process). The secondaries from scraping in the decay pipe region are modestly reduced in the discrete shielding configuration.

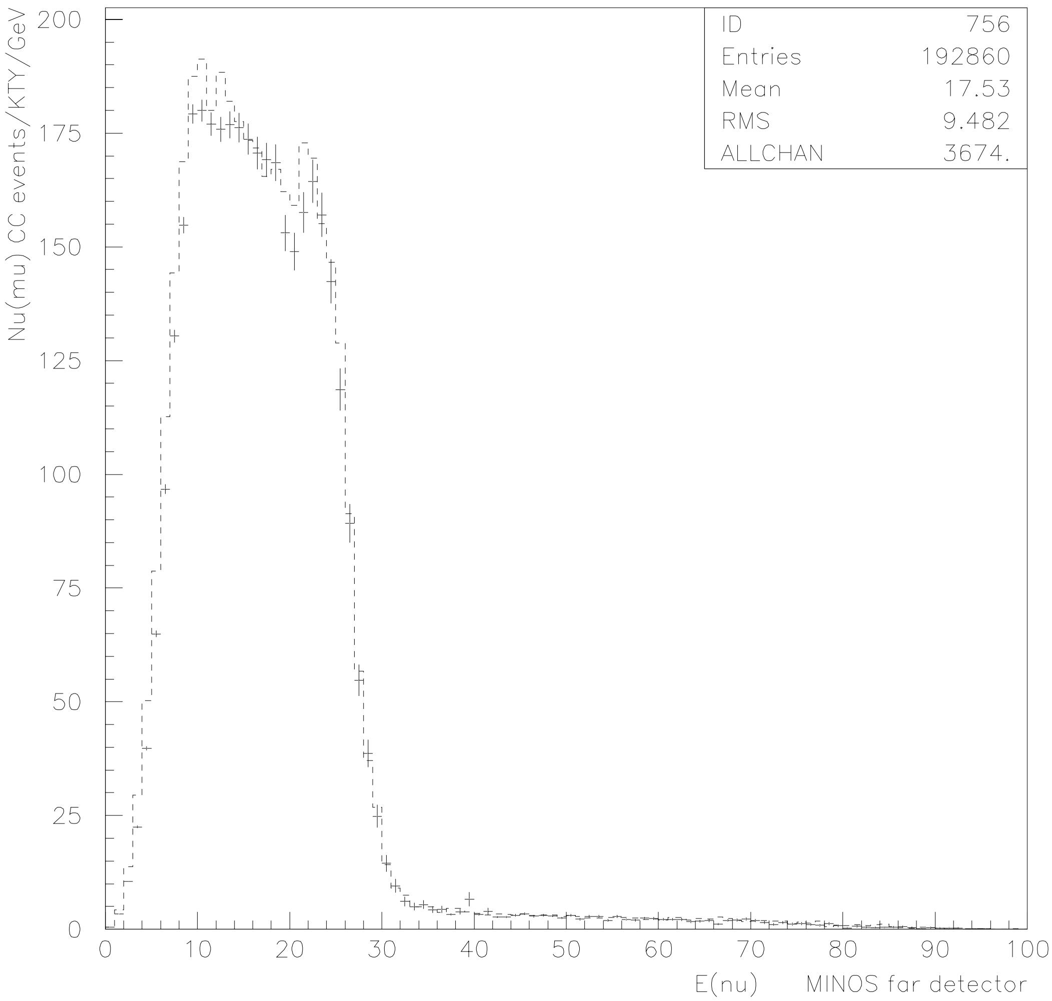

Figure 3: $\nu_m u^{CC}$ neutrino event spectra in MINOS. The data points are for the discrete shielding case, the dashed histogram for the continuous shielding case.

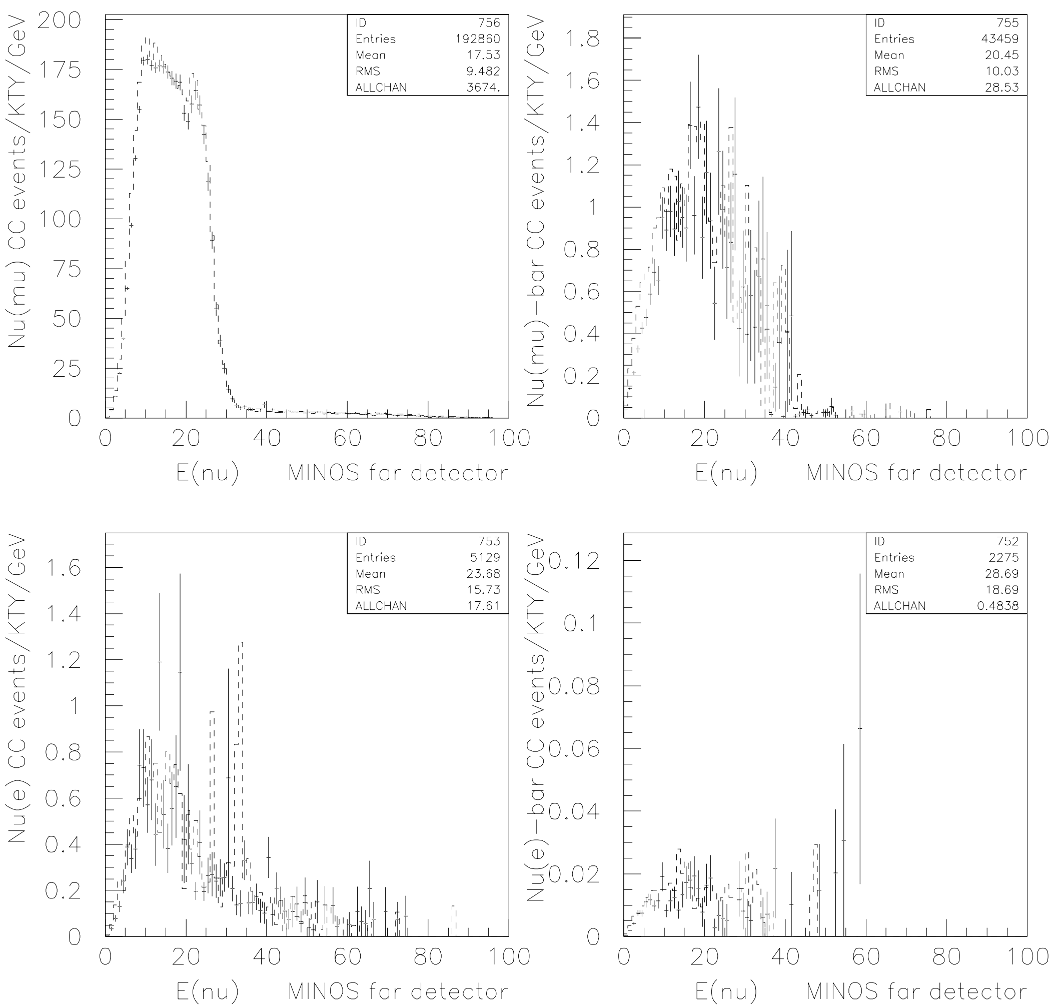

Figure 4: Neutrino event spectra in MINOS for different neutrino species. The data points are for the discrete shielding case, the dashed histogram for the continuous shielding case.

ν_μ^{CC} *events* per kilo-ton per year	Continuous Shielding	Discrete Shielding
From Target		
π	3546. ± 18.	3388. ± 17.
$K^{\pm}2-body$	177.8 ± 2.2	164.7 ± 2.1
$K^{\pm}3-body$	4.31 ± 0.23	4.61 ± 0.27
K_L^0	0.69 ± 0.11	0.44 ± 0.07
Secondary		
μ decay	0.021 ± 0.009	0.0018 ± 0.0010
K_S^0 etc.	42.0 ± 1.3	38.3 ± 1.3
Horns	83.1 ± 2.1	77.9 ± 2.5
Concrete	0.00049 ± 0.00007	0.000067± 0.000024
Target Hall FE	0.364 ± 0.039	0.30 ± 0.05
Decay Pipe Window	0.75 ± 0.24	0.34 ± 0.12
Decay Region Iron	4.57 ± 0.27	0.62 ± 0.11
Hadron Absorber	0.048 ± 0.011	0.022 ± 0.005
$\overline{\nu}_\mu^{CC}$ *events* per kilo-ton per year	Continuous Shielding	Discrete Shielding
From Target		
π	21.4 ± 1.4	20.1 ± 1.4
$K^{\pm}2-body$	1.30 ± 0.10	1.11 ± 0.08
$K^{\pm}3-body$	0.047 ± 0.014	0.030 ± 0.011
K_L^0	0.425 ± 0.057	0.24 ± 0.05
Secondary		
μ decay	4.83 ± 0.47	3.94 ± 0.35
K_S^0 etc.	0.82 ± 0.10	0.73 ± 0.21
Horns	2.81 ± 0.36	1.87 ± 0.23
Concrete	0.00018 ± 0.00013	0.000034 ± 0.000024
Target Hall FE	0.079 ± 0.008	0.123 ± 0.027
Decay Pipe Window	0.21 ± 0.07	0.21 ± 0.07
Decay Region Iron	1.11 ± 0.08	0.141 ± 0.029
Hadron Absorber	0.0055 ± 0.0013	0.026 ± 0.016

Table 2: Sources of ν_μ^{CC} and $\overline{\nu}_\mu^{CC}$ events in the MINOS detector.

$\nu_e^{CC} events$ per kilo-ton per year	Continuous Shielding	Discrete Shielding
From Target		
$K^{\pm}3-body$	8.42 ± 0.40	8.35 ± 0.41
K_L^0	1.26 ± 0.13	0.93 ± 0.16
Secondary		
μ decay	9.7 ± 1.2	8.0 ± 0.9
K_S^0 etc.	0.0010 ± 0.0008	0.00042 ± 0.00031
Horns	0.227 ± 0.035	0.31 ± 0.08
Concrete	0.000100 ± 0.000036	0.0000013 ± 0.0000012
Target Hall FE	0.0073 ± 0.0017	0.0071 ± 0.0035
Decay Pipe Window	0.009 ± 0.005	0.0008 ± 0.0008
Decay Region Iron	0.083 ± 0.013	0.0085 ± 0.0038
Hadron Absorber	0.00052 ± 0.00019	0.00021 ± 0.00005
$\overline{\nu}_e^{CC} events$ per kilo-ton per year	Continuous Shielding	Discrete Shielding
From Target		
$K^{\pm}3-body$	0.041 ± 0.010	0.049 ± 0.013
K_L^0	0.419 ± 0.046	0.39 ± 0.07
Secondary		
μ decay	0.0074 ± 0.0031	0.00045 ± 0.00027
K_S^0 etc.	0.00023 ± 0.00015	0.0000017 ± 0.0000011
Horns	0.042 ± 0.009	0.042 ± 0.016
Concrete	0.0000063 ± 0.0000027	0.0000021 ± 0.0000017
Target Hall FE	0.0019 ± 0.0005	0.00104 ± 0.00019
Decay Pipe Window	0.00020 ± 0.00012	0.000010 ± 0.000005
Decay Region Iron	0.022 ± 0.005	0.0017 ± 0.0005
Hadron Absorber	0.00015 ± 0.00009	0.00049 ± 0.00035

Table 3: Sources of ν_e^{CC} and $\overline{\nu}_e^{CC}$ events in the MINOS detector.

4 Conclusions

There is a fairly small (5%) decrease in the ν_μ charged current event rate in the case of the discrete shielding. The wrong flavor backgrounds are reduced by somewhat larger amounts, although this is only a couple standard deviation effect with current Monte Carlo Statistics.

In the neutrino energy region of a few GeV, the impact on the ν_μ charged current rate is larger. This points out that the smaller radius in the early part of the decay pipe is probably not ideal if NuMI/MINOS wants to shift to a lower energy neutrino beam at some point.